Space Weather Technical Forecast

Issued on Thursday, 16 December 2021 at 12:50 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Numerous sunspots on the earth-facing disc. Daily Chance of M-class flares, potentially increasing.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar Activity was Low in the past 24 hours, with occasional small C-class flares observed at GOES 16, peaking with an impulsive C4.4 at 15/1434UTC. This flare emanated from perhaps the largest and most complex sunspot group on the disc, 2907, which now appears as a Dai/Beta-Gamma having undergone rapid proliferation in its trailing spots. This is one of at least six sunspot groups on the disc at present.

Other groups of note include the one to its immediate east, 2908, which also saw significant growth, this time in its intermediate spots. There are signs that this area of growth may be a distinct region - for developing significantly to the north of the bulk of the rest of the group - even if they are interconnected magnetically. This group finished the 24 hours as a Dai/Beta. 2906 in the southern hemisphere near the middle of the disc also saw slight growth in its trailing spots, this reaching Csi/Beta-Gamma.

To round off the current roster of front-side groups, a sunspot region was numbered in the northern hemisphere near the meridian in the period as 2910, a Bxo/Beta. An Axx Alpha in the form of 2905 maintained its tenuous position near the meridian, while 2909 to its east saw consolidation to become a Dao/Beta near the southeastern limb. Finally, a possible new unnumbered region was noted - lying near the northeastern limb.

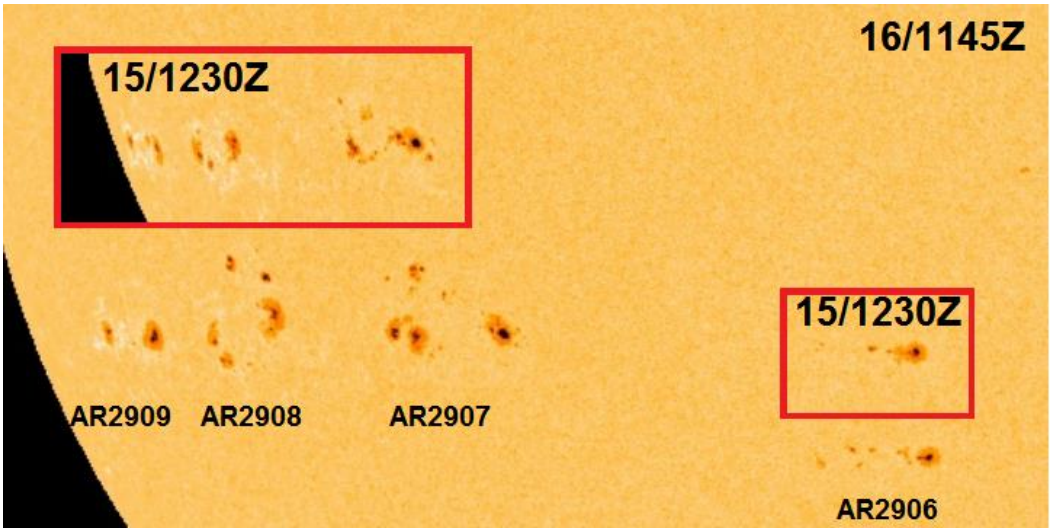

Figure 0: 24-hour evolution of the four foremost susnpot regions on the visible disc at present in HMIIF imagery. Compare the (red boxed) inset images with the latest to see AR2907 and also AR2908 as growing significantly.

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No Earth-directed Coronal Mass Ejections (CMEs) were observed in available satellite imagery for the period, although several large peripheral eastern horizon events were noted, as well as very faint and narrow west limb occurrences.

Solar Wind / Geomagnetic Activity: Earth is currently sampling the fast wind from coronal hole 32 - a now mature negative polarity feature, with the phi angle consequently towards the sun throughout. The solar wind speed has remained relatively stable between limits of 500-550km/s through the period, while the solar wind density showed a slight decline, passing through 10ppcc en route to background levels. The IMF also showed a modest decline from a peak 9nT, with the north-south component varying between +7/-8nT.

The net result of these solar wind measures was mostly Quiet geomagnetic activity, with a provisional peak Kp of Unsettled '3o' observed in the 15-18UTC window.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) remained at Background levels. The high energy electron flux (greater than 2 MeV) was at mainly Background levels, with the associated 24-hour integrated fluence well below the Active threshold. A fluence of 1.92e6 was observed at 16/0000UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar Activity is expected to be Low, but with a Chance of rising to Moderate given a congested eastern solar hemisphere. Further potential regions are likely to arrive over the eastern limb in the period, while none should leave, meaning the risk of significant flares ought to increase over the coming weekend. For now, C-class flares are Expected, while there is a Chance of M and a Slight Chance of X class events.

Solar Wind / Geomagnetic Activity: No CMEs feature in the current forecast period. Earth is currently in a mature high speed stream (from CH32), with this expected to wane into the coming UTC weekend. Confidence lowers hereafter, however a previous coronal hole (that by persistence should be due in the period) appears to have largely closed, meaning instead that an early peak of occasional Unsettled intervals should revert to Quiet into the weekend.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels, although with a slight increasing risk with time as the eastern hemisphere active regions continue westward with time.

The high energy (greater than 2 MeV) electron flux, as observed by GOES-16, is expected to be at Background to Moderate levels initially. While an upward reaction to the current high speed stream in both flux and fluence is expected to round out the current working week, the lack of a sizeable succeeding coronal hole (much-diminished from last rotation) ought to mean a departure from persistence in the period, with fluence probably peaking on Friday 17 December (day two) and probably falling short of Active before waning.

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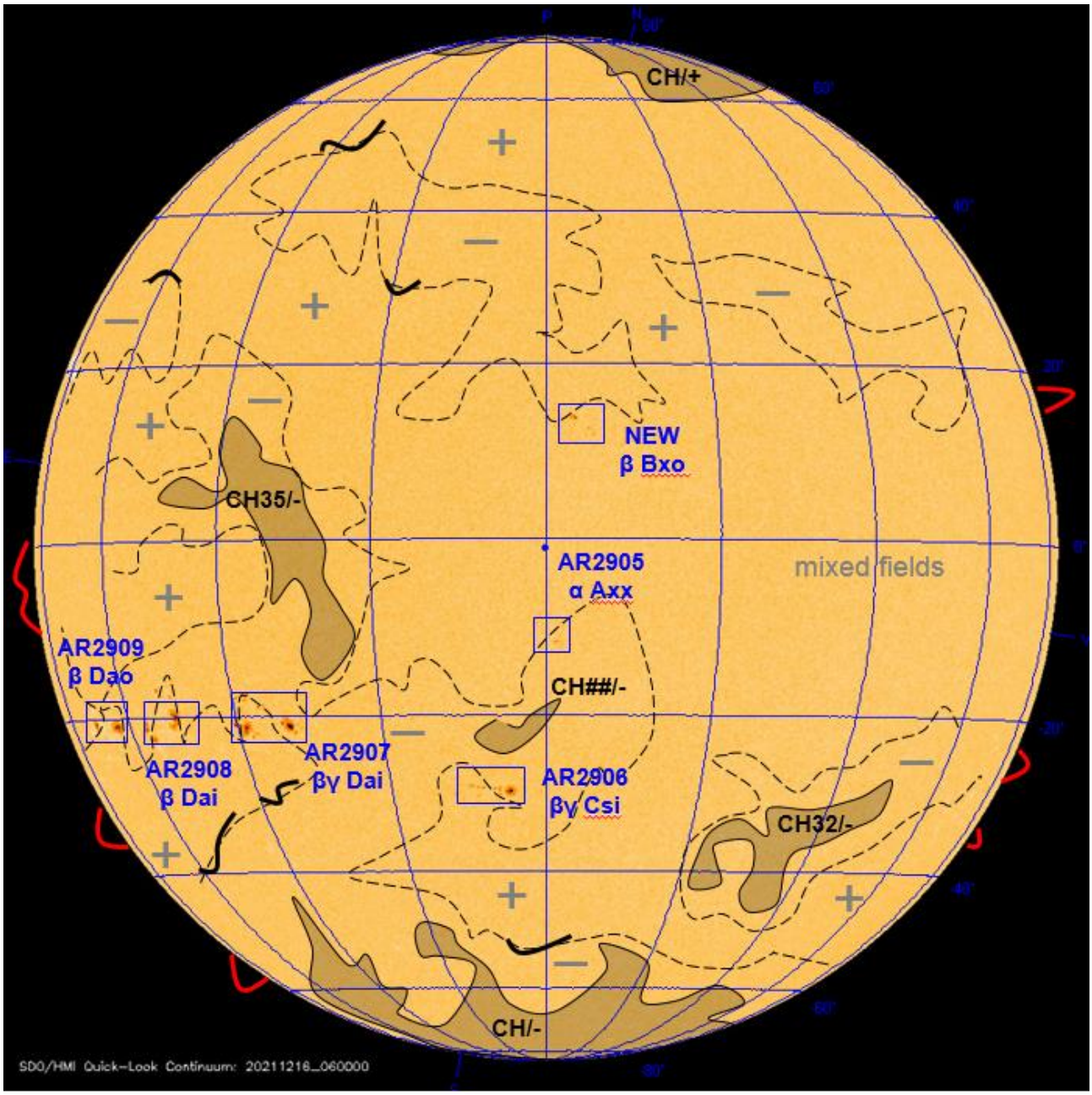
Figure 1. Solar Analysis Valid 16/0600UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

No Earth-directed CMEs feature in this forecast.

The current fast wind is thought to emanate from coronal hole 32, with effects from this feature now likely to be past their peak, with a gradual waning expected into the UTC weekend. In terms of forthcoming coronal holes, the disc bears little resemblance to last pass, with the train of sunspot regions and flux emergence near 20 South acting to (mostly) close a previously observed coronal hole in this area. Persistence forecasts are therefore not favoured on this occasion, although there appears to be a small vestigial remnant of the earlier coronal hole that may just prove capable of Unsettled intervals.

Larger and more intense coronal hole 35 is currently thought to lie outside the four day forecast period in the sun's eastern hemisphere, perhaps becoming geoeffective into the new working week UTC. Coronal holes of any polarity are near their semi-annual minimum potency at present (winter solstice), however there is perhaps a Slight Chance of G1 from CH35 - to perhaps be confirmed once it shows its hand at STEREO A.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	1	1	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Nil.

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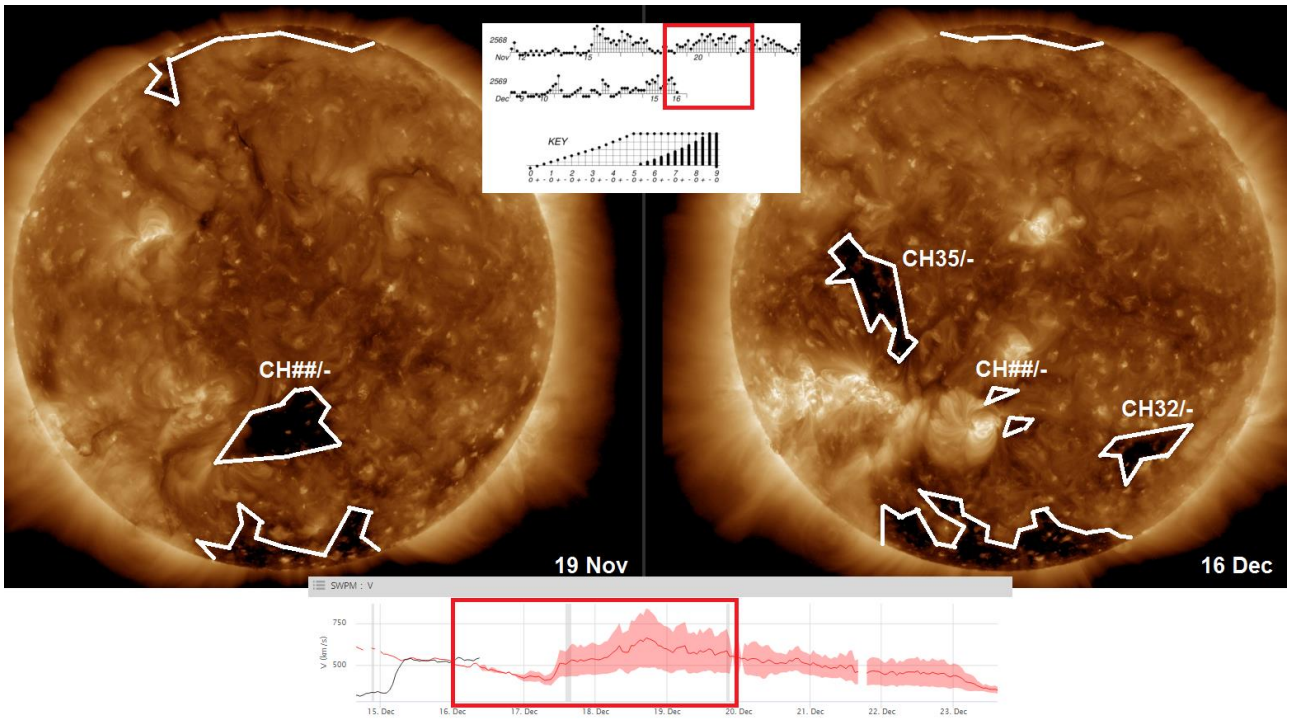
Figure 2: AIA 193 comparison between the previous and current rotations, showing significant departure in the features labelled CH##/- and CH35. CH32 is present, but has retrogressed since last pass, helping to explain its 'late' arrival.



Radio Blackouts - X-Ray Flares:

There are currently six numbered sunspot regions on the solar disc, with a potential seventh showing as plage near the northeastern limb. The current Earth-facing solar disc is showing a heavy weighting towards a more active and bipolar eastern solar hemisphere. This appears to continue onto the far side in the east, with STEREO A EUVI imagery and soundings showing several further possible active regions that may arrive in the period, while none should leave.

Of the current regions, 2907 and 2908 have shown strong growth and proliferation, also seen to a lesser extent in 2906. This growth is in addition to these regions being the most complex, with 2907 perhaps topping this list in its Dai Beta-Gamma classification, with strong growth in its trailing spots. Also of note was the emergence and numbering of 2910 in the northern solar hemisphere, although this group is currently much simpler.

Despite the current complexity of the disc and the rapid increase of other measures of activity (e.g. Penticton flux rising at its fastest daily rate so far this cycle as part of its rise from 76sfu on 12 December to 103 on 15 December), this has so far not borne out as significant flares of M or X class. Despite this lack of 'ground truth', the risk is felt to be there for larger flares, with a probable rise over the coming weekend as more regions bring themselves to bear on the overall probability.

C-class flares are thus Expected through the four days, with a Chance of M-class and a Slight Chance of X. While the expected trend is upward, this will manifest in the issued probabilities once there is evidence of regions arriving over the eastern limb from an Earth-perspective.

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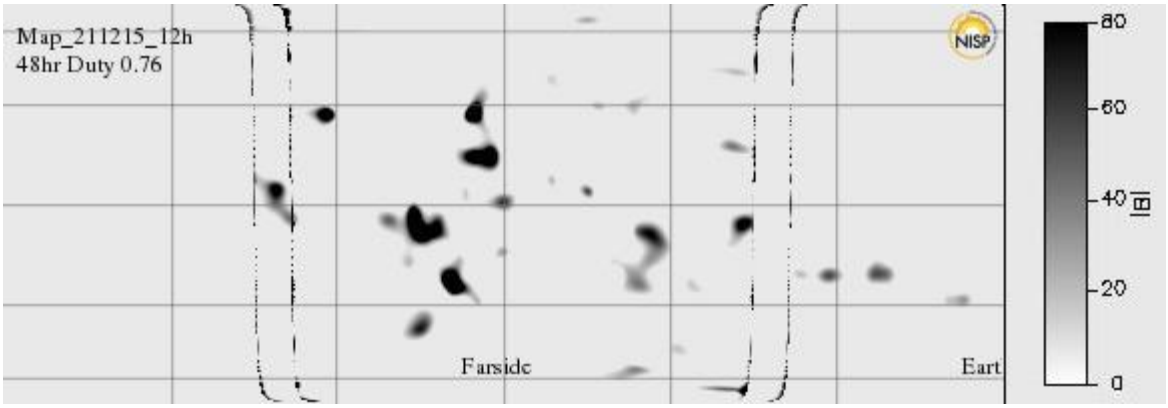
X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	No	30	30	30	30
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 3: NSO GONG Calibrated Farside Map, showing possible active regions invisible from Earth as impending in the four-day period, potentially adding to an already congested front side.



Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) as observed by GOES-16 is currently expected to remain at Background levels. Increasing sunspot activity may warrant a slight increase of chance of S1 radiation storming over the next few days, though at present the most significant active regions are in the eastern hemisphere of the solar disc. As a result any large flares are less likely to cause Solar Radiation Storms at Earth.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	≥ S1	No	1	2	2	5
Very Active	≥ S3 *	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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High Energy Electrons Event (≥ 2MeV):

The high energy (greater than 2 MeV) electron flux, as observed by GOES-16, is expected to be at Background to Moderate levels initially.

The 'brakes' of geomagnetic activity from the current coronal hole 32 high speed stream should be released over the coming hours, such that the resultant reaction of electron flux at GEO should become known. The current peak solar windspeed is delayed and diminished relative to last pass of the equivalent feature, which should mean that fluence ought to track below the Active threshold (as last pass should have been more potent) - even at peak - although a slight upward fluence trend is still likely.

Later in the four days, persistence methods become unfavoured, with a previous incumbent coronal hole to 650km/s now largely closed by the emergence of a train of active regions in its place. Because this feature will be muted if even present, and because the next coronal hole of any note (CH35) ought to fall outside the period, soon-to-be-reached flux and fluence levels from CH32 should be the peak for the period, with chances reducing thereafter.

The latest REFM model does show a forecast gradual rise in fluence over the next 72 hours, and while this is expected to hold true in general, the forecast expected departure from persistence ought to decrease its usefulness into the coming weekend.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^{8}$**	No	1	30	20	20
Very Active	**≥ 2 MeV ≥ $1x10^{9}$**	No	1	1	1	1

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